Bonneville Power Administration
Fish and Wildlife Program FY98 Watershed Proposal Form

Section 1. General administrative information

Title Engineered Channels For Natural-Type Chinook Salmon Production

Bonneville project number, if an ongoing project 8070

Business name of agency, institution or organization requesting funding
Aquaculture Research Institute

Business acronym (if appropriate) ARI:UI

Proposal contact person or principal investigator:

Name Ernie Brannon
Mailing Address Aquaculture Research Institute
University of Idaho
City, ST Zip Moscow, ID 83844-2260
Phone 208-885-5830
Fax 208-885-5968
Email address aqua@uidaho.edu

Subcontractors.

Organization	Mailing Address	City, ST Zip	Contact Name
Washington State University	100 Sprout Rd	Richland, WA 99352	Bill Kinsel
USFWS	12790 Fish Hatchery Rd	Leavenworth, WA 98826	Greg Pratschner
River Masters Engineering	PO Box 306	Pullman, WA 99163	Tom Bumstead

NPPC Program Measure Number(s) which this project addresses.
4.1A, 7.2, 7.4A, 7.6A, 7.6B, 7.6D, and 10.5

NMFS Biological Opinion Number(s) which this project addresses.
n/a

Other planning document references.

Watershed project is supported by US Fish and Wildlife Service MOU
NSF grant on Habitat Development for Salmonids
Washington State Legislature

Subbasin.
Icicle Creek in the Wenatchee subbasin

Short description.
Construction of an engineered stream channel in Icicle Creek at the Leavenworth NFH as a new concept in natural-type chinook salmon production supplementation.

Section 2. Key words

Mark	Programmatic Categories	Mark	Activities	Mark	Project Types
X	Anadromous fish	X	Construction	X	Watershed
*	Resident fish		O & M		Biodiversity/genetics
	Wildlife		Production		Population dynamics
	Oceans/estuaries	*	Research		Ecosystems
	Climate		Monitoring/eval.		Flow/survival
	Other		Resource mgmt		Fish disease
			Planning/admin.	*	Supplementation
			Enforcement		Wildlife habitat enhancement/restoration
			Acquisitions		

Other keywords.

Section 3. Relationships to other Bonneville projects

Project #	Project title/description	Nature of relationship
8906500	Supplemention Production	New hatchery concept

Section 4. Objectives, tasks and schedules

Objectives and tasks

Obj 1,2,3	Objective	Task a,b,c	Task
1	Develop & evaluate channel	a	Make site survey

		b	Develop model
		c	Complete specifications
		d	Channel construction
		e	Develop density/feeding strategy
2	Develop fish passage	f	Develop fish access
		g	Riparian development
		h	Wetland management
		i	Education/Interpretation
	Note: following table repetative number of the objective refers to the seqence of tasks		

Objective schedules and costs

Objective #	Start Date mm/yyyy	End Date mm/yyyy	Cost %
1	4/1998	5/1998	3.00%
1	6/1998	9/1998	4.00%
1	10/1998	3/1999	3.00%
1	4/1999	10/2000	80.00%
1	11/1999	6/2001	3.00%
2	6/1999	8/1999	2.00%
2	6/1999	10/2001	2.00%
2	6/1999	10/2001	2.00%
2	11/1999	6/2001	1.00%
			TOTAL 100.00%

Schedule constraints.
Timeline for USFWS to secure environmental assessment and permits

Completion date.
2001

Section 5. Budget

FY99 budget by line item

Item	Note	FY98
Personnel	because this is a watershed proposal, the fiscal year starts in FY98, please note for budget years	$67,252
Fringe benefits		$11,652

Supplies, materials, non-expendable property		$9,500
Operations & maintenance		$2,000
Capital acquisitions or improvements (e.g. land, buildings, major equip.)	FIDAP - capable PC	$10,000
PIT tags	# of tags:	$0
Travel		$2,140
Indirect costs		$78,474
Subcontracts		$85,000
Other		$0
TOTAL		$266,018

Outyear costs

Outyear costs	**FY99**	**FY00**	**FY01**	**FY02**
Total budget	$1,650,000	$22,000	$22,000	
O&M as % of total	0.01%	0.05%	0.05%	

Section 6. Abstract

An engineered stream is proposed as a new concept in watershed salmonid supplementation to revive salmonid habitat disrupted by river development. In collaboration with the USFWS, research on engineered streams is proposed by UI/WSU as a long-range ecosystem alternative to hatcheries for supplemention of weak or failing salmonid populations. The objectives are to provide resident fish passage to a watershed prevented by a barrier dam and to demonstrate the viability of natural-type engineered streams for chinook salmon (*Oncorhynchus tshawytscha*) production that match wild smolt quality and performance. Nine tasks are to (a) make the site survey, (b) develop a channel model, (c) complete specifications, (d) channel construction contract, (e) develop density/feeding strategy, (f) develop fish access, (g) riparian development, (h) wetland management and (i) education/interpretation programming. The project is relevant to watershed concerns about mitigation, anadromous species supplementation, resident fish, and habitat improvement. The approach is to develop the stream channel with engineering specifications based on biological and ecosystem criteria, and develop rearing strategies to optimize production, while maintaining genetic specificity, diversity, and natural smolt quality. The demonstration site selected is the Icicle Creek by-pass channel at the Leavenworth NFH where a stream channel, flow control structures, dikes and monitoring capability are already in place. Expected results will be a

supplementation tool that markedly improves survivability of enhanced chinook stocks. Post-study monitoring will be accomplished by USFWS assessment of smolt quality, emigration success, and marked adult return success compared to standard hatchery production.

Section 7. Project description

a. Technical and/or scientific background.

Background

Declines in abundance of anadromous fish runs in the Columbia River drainage are attributable to a number of factors, including loss of spawning and nursery areas due to dams, mortalities of both juvenile and adult fish at hydroelectric developments in the migratory corridor, and reduced habitat quality in areas still accessible to anadromous fish. Salmon hatcheries in the Columbia Basin, developed to mitigate for the loss of habitat and natural production, are also considered part of the problem associated with loss of natural production through decreased genetic diversity (Ryman and Ståhl, 1980; Allendorf and Utter, 1979; Allendorf and Phelps, 1980; Cross and King, 1983; and Ståhl, 1983), and poor conditioning (Swain and Riddell, 1990).

The perpetual oversight that has been demonstrated consistently throughout the history of fisheries management has been to ignore the fact that fish populations are an integral component in a complex environmental ecosystem. A general disregard for stock structure and the synchrony between genetic attributes of populations and the environment associated with their natal systems has characterized many hatchery programs. An important point that needs to be kept in mind, however, is mid-century hatcheries were developed as production facilities to mitigate for the loss of habitat and over fishing, and thus were not intended to enhance natural production, for which present supplementation programs were developed. However, even the supplementation hatcheries have not been producing adult returns comparable with naturally spawning populations (Lichatowich and Mobrand, 1995). The problem is believed related to smolt quality. Snake River wild smolts survive the rigors of smolting and downstream passage through the hydroelectric complexes of the Lower Snake and Columbia rivers at a higher rate (2 to 5%) than hatchery produced smolts (0.02 to 0.05%) (S. Patterson, IDF&G, personal communication). Although wild fish have experienced higher mortality before they become smolts, and therefore represent lower total survival to return than when considering just the smolt stage, the point remains that hatchery fish need improvement in overall performance if major progress is to be made in supplementation programs.

It is argued that the a long-term plan has to be developed around a different approach to supplementation. Three essential elements for successful supplementation must include, (1) the genetics of the stock, (2) the environmental requirements of the stock, and (3) incubation and rearing experiences that are consistent with the life history of the species. These three elements have to become central in the supplementation programming process. As an integral component in a complex environmental system, salmonid stocks evolved in synchrony with their environment. Spawning time, emergence timing, juvenile behavior and distribution are not random, but rather occur in specific patterns of time and space for each population (Brannon, 1984). The seed stock, habitat, and the appropriate technology are the keys to producing fish that will be functional when entering the natural stream system.

Project description

The project is to revise chinook salmon supplementation by the use of engineered rearing channels that represent natural habitat. As an alternative to traditional hatchery methodology, a new concept is to develop incubation and rearing environments in constructed streams, engineered to provide optimum habitat based on natural stream conditions experienced by chinook alevins, fry, and fingerlings.

The design of the engineered production facilities will take the form of a simulated stream with pool and riffle environments that promote the production of natural feed, and stocked at lower rearing densities compared to standard hatcheries. The approach will be to develop the specifications of the engineered stream using an engineered model that integrates the dynamics of the site and chinook salmon habitat requirements, construct the engineered stream channel, and establish the optimum rearing strategy to produce high quality smolts based on smolt condition criteria and adult return success. Biological and engineering expertise will be integrated to develop rearing strategies to improve the quality of fish that must compete in the natural environment.

The site selected for the demonstration project and in collaboration with USFWS is Icicle Creek, specifically on the by-pass stream-bed around the barrier dam adjacent to the Leavenworth hatchery (Fig. 1) and part of the USFWS property. The by-pass stream is the original river channel. After construction of the hatchery the by-pass stream was used for holding adult salmon in hatchery mitigation projects, but has since silted-in and has been abandoned as the need for such holding capacity diminished. The by-pass stream-bed is 1400 m long and varies from 25 m to 50 m in width. Headworks and tailworks that control flow and fish access through the by-pass stream are already present. Working head over the by-pass stream length is approximately 20 feet. In addition, two weirs also span the stream-bed that provide ready-made structures to assist partitioning sections of the channel to assure distribution of spawners if natural spawning is to occur over the constructed channel facilities, and for monitoring fingerling dispersal and migratory behavior. As a side stream of the main body of water passing down Icicle Creek, the water quality is the same as the natural stream. The adjacent riparian areas to the stream have developed naturally and will be enhanced for cover and shade, and to stimulate natural food production.

The ultimate goals of the project are to demonstrate the (1) effectiveness of the new concept in supplementation, and (2) to provide recovery of habitat potential of the basin cut off when the Leavenworth NFH was built. The new concept will be addressed by reviving the abandoned stream-bed for supplementation rearing. This will be accomplished by the development of optimum rearing strategy in specific engineered stream channels by establishing the most effective habitat for producing natural-type smolts, including habitat criteria, fish density, predation, and supplemental feeding regimes.

The construction the Leavenworth NFH blocked migration of resident species such as bull trout and anadromous salmonids from accessing the Icicle Creek basin. Revival of the abandoned by-pass channel for managed natural rearing habitat will also provide upstream access of migrating species to the basin. Siltation of the abandoned channel has been severe, but it has created wetland areas. Riparian and wetland enhancement will improve the wildlife features of the area and increase the productivity of the engineered channel environments. Finally, the education benefits associated with the facilities will be outstanding. Interpretation of the engineered stream, resident fish by-pass, and riparian/wetland development will give extraordinary opportunities to observe ecosystem functions at work to produce highly fit anadromous salmonids.

Project costs
The project proposal for the engineered stream is in three phases that include (1) planning and design specifications, (2) engineered stream and passage construction, and (3) rearing strategy development. Phases 1 and 2 prepare the ability for the ultimate objective around phase 3. Therefore, the budget proposal is a joint sponsorship that is proposed through a primary contract with UI. Phase 1 will be conducted through the UI/WSU/USFWS team, with the proposed first year budget . Phase 2 construction cost will depend on the design specifications for the particular site, and the budget, therefore, is soft and will be finalized after the first year. Phase 3 will be undertaken by UI and USFWS personnel to establish optimum rearing strategy. Some of Phase 1 and 3 costs are paid from sources other than the requested funds. The channel facility will become part of the USFWS Leavenworth NFH operations and will be maintained and monitored as part of the NFH program.

b. Proposal objectives.

Goals:

1. To develop natural-type engineered habitat for salmonid production to imitate wild smolt quality and survival to adult return in areas where habitat has been lost or in need of supplementation.
2. To revive production potential of Icicle Creek watershed basin cut off by a barrier dam constructed as part of the Leavenworth NFH program.

Objective:

1. To produce wild-quality fingerlings and smolts from engineered stream channels for supplementation of chinook runs diminished by limited habitat and river development.
2. To recover steelhead and resident fish access to Icicle Creek basin, Wenatchee River system, eliminated by construction of Leavenworth NFH barrier dam.

Hypothesis:

The null hypothesis (1) in this project is:

Ho: Chinook reared in stream channels engineered to mimic natural stream habitat under a natural, supplemented feeding regime during residence, upon release, and emigration will perform no different than standard hatchery fish in raceway environments.

Corollary: Rejection of the null hypothesis will indicate that fish reared in engineered natural-type streams behave differently, are prone differently to disease and predation, and respond differently to stress associated with emigration passage downstream.

Rejection of Ho: The null hypothesis will be rejected if engineered stream channel fingerlings or smolts show differences in behavior patterns, relevant mortality during residence, quality indices, smolt stress sensitivity, predator avoidance, or migratory success to monitoring stations on the Columbia River.

The null hypothesis (2) in this project is:

Ho: Steelhead and resident fish passage and migration to stream reaches above the Icicle Creek barrier dam is not enhanced by provision of fish passage facilities through the engineered stream by-pass.

Corollary: Rejection of the null hypothesis will indicate that steelhead and resident fish below the barrier dam on Icicle Creek use passage facilities provided by the engineered stream by-pass.

Rejection of Ho: The null hypothesis will be rejected if pre-adult or adult anadromous steelhead or resident fish species are found to use the engineered stream channel by-pass to the Icicle Creek basin.

c. Rationale and significance to Regional Programs.

This alternative production concept with the local stock in facilities that mimic the biological habitat of the fish sufficiently well to produce wild-type smolts, is anticipated to become a major part of chinook, coho, and steelhead conservation management associated with supplementation. The engineered channel research project for Icicle Creek represents a potential major change in supplementation strategy. If the strategy is successful in providing natural-type quality fish, the concept will have substantial long-range implications on hatchery production and contribution in the future. This project will provide the necessary background information on engineered streams to assist in up-grading or replacing traditional hatchery practices in supplementation. This project will also be a model for rearing channel systems that can be used to supplement degraded streams or to replace habitat lost from hydro development. Costs associated with such alternatives to standard hatchery construction and production would be substantially reduced, but more importantly, engineered channels would provide enhancement of local stocks within the environments and critical temperature regimes peculiar to the local basin.

The concept is an alteration of the approach used for sockeye salmon (*O. nerka*) in British Columbia. Sockeye, as a species that rears in lakes rather than streams, were limited primarily by less than optimum stream spawning areas. Spawning channels, therefore, were developed to address the habitat constraints of that species (Cooper, 1977). Engineered channels were constructed with graded substrate and controlled flow that resulted in incubation survival rates as high as 10 times natural incubation success. Weaver Creek spawning channel is a good example of such a project (Fig. 2), and has demonstrated a stock enhancement performance in excess of 200% of its previous annual production history. As a stream resident species during their freshwater rearing phase, chinook have been affected most by reduction or limitation of available stream rearing habitat. It is perceived, therefore, that by providing optimum rearing habitat and nutrition, similar success can be achieved with this species. While incubation and rearing channels require different specifications from that of spawning channels, the general concept is the same, under the numerical and density constraints of the species.

The project will have critical linkages to the Leavenworth NFH program and hatchery assessment. Evaluation and control comparisons will be integrated with the tagging and smolt interception programs of Leavenworth NFH chinook emigrants at monitoring stations downstream in the Columbia. Ancillary benefits are that the channels provide passage of steelhead and bull trout to the upper portion of Icicle Creek, previously prevented by the barrier dam at the hatchery. In addition the project will provide extended educational opportunities of the concept of integrating management with ecosystem functions at work to produce highly fit anadromous salmonids.

d. Project history

New project

e. Methods.

As listed above in the Section 4 nine tasks are outlined to address the objectives associated with development and evaluation of the stream channel and development of fish passage. The nine tasks are, nine tasks outlined are (a) make the site survey, (b) develop a channel model, (c) complete specifications, (d) channel construction contract, (e) develop density/feeding strategy, (f) develop fish access, (g) riparian development, (h) wetland management and (i) education/interpretation programming. The conceptual plan for the stream channel will identify stable channel and habitat features. This will include assessment of existing stream-bed conditions, and integration of the biological and engineering design criteria to develop conceptual designs for the rearing channel alignment and structures within the project area. Each of these designs will be evaluated for channel stability, habitat features, constructability, design life, and maintenance. A thorough understanding of the existing physical conditions within the project area will identify features and areas needing special consideration so the plan can to meet the project objectives. From this evaluation, the design, or combination of designs, that create the best channel configuration and target species habitat features will be developed in the hydraulic model. For the Icicle Creek stream channel project, the analysis of existing conditions will include (1) hydrologic analysis, (2) biological consideration and habitat utilization, and (3) project area survey.

Hydrologic analysis will determine characteristic flows at the project site to identify the range of discharges appropriate for stream channel design and habitat features with species requirements. A topographic survey will be completed to define the location and elevation of the physical features within the project area, including existing channel features upstream and downstream of the project site. Local hydrologic characteristics determining natural flow regimes create a wide variety of conditions that must be considered during the design of projects within any river system. Even with the protection of flow control facilities, engineered stream channels must be designed to withstand flushing flows, maintain fish habitat features, and transport suspended sediment without depositing large quantities of this sediment in the rearing channel. Determining background flows for the Icicle River project will utilize existing USGS streamflow records for the Icicle River above Snow Creek and a regional hydrologic model to determine flood, average, and low flows. Gauging station records to be used in the development of this model will include streamflow records for the Icicle River and, if necessary, records for streams in the Wenatchee River, Entiat River, Snoqualmie River, Skykomish River and Upper Yakima River Basins. Average annual flow, seven-day average low flow, average flood flow and average daily flood flows with a 20- and 50-year recurrence interval will be determined. Average monthly flows to be estimated will include monthly minimum, mean monthly and monthly maximum.

Project area survey

Existing physical characteristics within the project area will be surveyed using project benchmark reference sites to established on or near a prominent physical feature within the project area. Cross reference will be made with a nearby USGS benchmark location. Additional temporary benchmarks will be established throughout the project area to provide vertical control during the design and construction phases as needed. All elevations determined within the project area will be relative to the project and temporary benchmarks. A Geodimeter System 400 electronic total station surveying instrument will be used to complete the site survey. Physical features such as edge of channel, existing topography, toe and top of road embankment, islands, edge of vegetation, secondary channels, and water surface elevations are located by determining the horizontal angle and distance to each feature from the instrument. Physical features will be determined with an accuracy of ± 0.5 feet horizontally and ± 0.1 feet vertically. All data collected by the total station will be stored in an electronic data recorder. Upon completion of the site survey, data stored in the electronic data recorder will be transferred into coordinate geometry software. In this program, the horizontal angle, vertical angle, and slope distance data recorded for each point is converted into northing, easting, and elevation coordinates. These coordinates along with point identification information are converted into a data exchange file (DXF) which is then input into AutoCAD™ to generate a site map of the project area. This map and the elevation data are then used in the design of the channel realignment and stabilization structures.

Design criteria

The biological and engineering design specifications for the engineered stream provide the base for the design drawings, and offer a detailed list of specific requirements or guidelines to maximize the engineering and biological benefits of the project. Under biological and habitat utilization criteria over the range of design flows occurring within the project area, hydraulic characteristics within the channel create the physical and biological conditions which produce the habitat features. Habitat utilization within the project area by the different age classes of the identified species is, therefore, a very important component in the design of rearing channel features. A habitat utilization table will be developed from biological experience and from the extensive literature. Design criteria will be based on criteria reviewed by Chapman and Bjornn (1968), Reiser and Bjornn (1979), Brett et al. (1982), Platts and Nelson (1989), Rubin et al. (1991), Murphy and Meehan (1991), and Rich et al. (1993). In this table, specific periods of the year will be identified for egg incubation, fry emergence, juvenile distribution, habitat features, downstream emigration. Information specific to the species in the Icicle River and Wenatchee River systems will be utilized as much as possible. Time periods in the habitat utilization table will be identified to the nearest week to coordinate the biological and hydraulic events of the project during the design of the rearing channel features. All in-channel structures and habitat features will be designed to ensure the greatest amount of habitat utilization within the rearing channels including preferred water depths and velocities, cover preferences, and substrate use and other hydraulic preferences. Utilization of these design criteria while developing channel realignment and stabilization features will ensure the hydraulics and instream structures maintain suitable habitat conditions over the freshwater residence period of the fingerlings.

Engineering specification criteria include channel features and instream structures that are designed with consideration given to the relationship between hydraulic geometry, channel shape, and channel gradient to stabilize channel cross section, channel profile, and riparian areas. All structures in the engineered channel will be designed to create the necessary habitat features with minimum alteration of any physical attributes or channel conformation with the range of flows specified in the design. Design criteria will include maximum flows, minimum flows, migration period flows, channel dimensions, channel length, control structure spacing, local channel gradient, and habitat feature installation. These criteria integrated with the biological utilization will ensure the channel structures create planned habitat attributes within the stream.

Hydraulic model
Model studies provide a preview of the operating characteristics of prototype structures. Modifications to improve the operating characteristics of the stream in the model are straight forward and accurately predict flow relationships in prototype structures. The hydraulic model is developed from the conceptual plan. Conceptual designs, based on the biological and engineering evaluation data and design criteria, will provide the channel features required to maximize rearing habitat in the engineered stream. Overall model dimensions and interior topography will allow the testing of desired combinations of habitat features and components. The length scales of the physical model(s) will be determined and the test matrix established. The model will then be constructed and calibrated, and testing and evaluation of the stream channel designs will commence. Production runs, data reduction and analysis (in view of performance criteria) will be undertaken. Each of the model tests will concentrate on evaluating the hydraulic performance of the design, the creation and maintenance of overall habitat features, and the creation of the preferred water depths and velocities for the target species. FIDAP modeling for scale-up and checking will be run, with sensitivity assessment using FIDAP. Transport properties will be addressed. Design of the auxiliary systems (feeding, back wash, pump, flow diversion) will have been taking place concurrently, and any affect of such systems of flow dynamics will be included in the assessment.

Project implementation
Project design drawings as the final element in the conceptual plan will utilize the information collected, analyzed, and tested during the engineering and biological evaluations, and hydraulic model tests in preparation for project implementation. The design drawings and construction specifications will include design preparation, construction specifications, and a cost estimate. Project design drawings for the Icicle River project will identify the location and types of features to be incorporated into the rearing channel. Using the conceptual plan identified during the hydraulic model testing, project design drawings will be completed to identify the location, alignment, and elevation of the rearing channel features. These designs will define the channel alignment and habitat features required to create the desired fish habitat components and features while satisfying the biological and engineering criteria. All drawings will be prepared using computer aided drafting software and plotted using a laser jet printer. Standard drawing format will be on 11 x 17-inch paper, however a 100 percent enlargement onto 22 x 34 inch paper can also be utilized when full size drawings are required.

Construction specifications
Preparation of construction specifications is the initial step in project implementation. Prior to beginning actual construction, each component of the implementation process must be identified using the project design drawings and evaluated to define the activities required to complete the project. Using this list of activities, specifications defining the construction methodology, materials, and equipment can be prepared. Construction specifications for the rearing channel installation within Icicle Creek by-pass will

consist of four components. These will include material quantities, material specifications, equipment specifications, and installation time estimates. Material quantities will be estimated using the project layout and installation details on the project design drawings. Excavation volumes and instream structure quantities will be developed during this analysis. Material specifications will be developed simultaneously with the material quantity estimate. These specifications will identify the size, type, and/or grade of each material to be used. Equipment specifications will be developed once the material quantities and specifications are determined. Standard installation times will be used to estimate equipment requirements and project completion times. These times have been developed using equipment performance charts and construction supervision experience. All construction specifications will be prepared using CSI format and will be included with the project design drawings on 3.5-inch computer floppy disks.

Engineered stream construction

Construction of the stream channels, based on the specifications, will take the form of two channels with equal surface areas and structures in each corridor in the shape of riffles, pools and glides. Pool and glides will be engineered to provide diversity of habitat, woody debris, cover, contoured walls and floors, and velocity retreats. Other habitat features such as cover, overhanging banks, and large (15 to 30 cm) rock will be represented in the corridors. Gravel will characterize the riffle areas. Channel length will be constructed in replicate, 100 m long sections with sills and migrant interception units separating each section for research purposes in developing rearing strategies. Twenty four, 100 m, replicate units will be represented in the combined channels.

Flow will be maintained through gate regulation at the headworks, and settling areas for sand provided in the form of the pools in the uppermost section behind the headworks barrier. Riparian habitat will be enhanced along each bank and on the barrier wall between corridors over the length of the channels. The area will be enhanced for wildlife by developing and expanding wetland and riparian habitat next to the engineered channels, and observation stations will be developed via viewing chambers below the water surface adjacent to habitat types to facilitate assessment of behavior and intraspecific competition.

The auxiliary systems will include sub-gravel surface grids of pvc pipe, with reinforced perforations or nozzles for cleaning the gravel across the floor of pools. A pneumatic design incorporating jets of water and air mixtures buried beneath the pool floor will be assessed for cleaning efficiency. Pipe inlets will extend from the grids to an access point on the bank of the western-most channel from which a vehicle mounted compressor can be hooked up.

Feeding systems will also be evaluated. Potentially, feeding stations will be positioned close above the surface of the shallow riffle reaches of each segment and feed supplemented with surface distributed in the riffle areas over the length of each channel. Water will be evaluated as the transport mechanism to distribute the feed from hoppers along the west bank of the paired channels.

Genetic diversity will be maximized by artificially spawning live fish and seeding the channel in special subsurface incubators to provide natural incubation and emergence behavior from ideally placed incubation sites. Artificial spawning live fish (20% of egg mass) will allow the channel to be seeded with five times the number of mating pairs than what would occur by natural spawning.

Icicle Creek is a natural stream subject to flooding, bed-load transfer, and low water at certain times of the year. Higher silt loads and flow fluctuations resulting from the recent fires that swept through the basin are expected in the short-term, and water temperatures exceed 20°C at times. Irrigation diversions also are taken from the stream. Some of these circumstances will be part of the environmental variables that will be included in the research planned, but to address these potential water quality and quantity problems, the following measures will be taken. (1) The project will use settling basins constructed at the headworks of the by-pass stream to capture sand and settleable solids carried by the river. Flushing flows and cleaning grids placed in the pool areas will carry silt downstream in the early summer seasons. (2)

The low flow circumstance will be met by installing pump return lines below the tailworks that can to return water to the headworks for supplementation of natural flow, if flow becomes limiting. (3) High temperatures will be addressed by the riparian cover along channel to minimize heating during the summer season.

Development of fish passage, wetlands and riparian areas
Steelhead and resident fish passage will be provided during the channel construction phase and will include low velocity submerged gate fishways to encourage bull trout to use the access route pass the tailgate and headgate structures. Passage will be routed through the wetland, and gravel sections will be developed for spawning purposes if selected to do so by the fish. Wetland enhancement, flow control and riparian plantings will be done to facilitate wetland habitat, cover, and access routes. Assessment of habitat use and passage will be by observation and upstream traps in the upper fishway before entering the river above the barrier.

Density and feeding strategies
The ultimate tests of the system will be done on comparative performance of chinook under different densities and supplementary feeding levels to assess optimum strategy for high quality smolts. Understandably, results will be site specific and will not necessarily reflect on what strategy may be optimal in other systems with different temperature regimes and environmental quality. Replicate studies will be done in the 100 m long stream channel units to provide statistical evaluation. Loading densities will range from 0.05 to a 0.1 loading index to reduce densities and assess its affect on growth rates, distribution patterns, condition index, disease, resident mortality, and migratory readiness. Feeding levels will be assessed using the same criteria, and with a factorial analysis interactions of density and feeding level can be assessed to determine optimum strategy.

Comparative performance will be based on qualities up through the smolt emigration phase, including survival to the smolt interception facilities on the Columbia River. When performance evaluations are made, hatchery controls for comparison of the project will be provided by Leavenworth NFH standard hatchery fish, using the following criteria: genetic diversity; fingerling quality and index of condition; smolt quality and index of condition; dispersal, distribution and migratory behavior; predator avoidance; stress tolerance; pathogen load; survival to smolt; survival to points of interception. The predator evaluation and other comparative performance studies with hatchery fish will be done in isolated 100 m stream channel units where assessment can be undertaken with replicated unmarked study lots. Stress analysis will be done under laboratory conditions using temperature tolerance (Bozeman stress test) handling, and fright behavior. The adult return success will be evaluated by USFWS after the termination of the study phase, and continued by USFWS as a operation and monitoring responsibility of the program. All fish released from the stream channels and NFH hatchery will be tagged proportionally for identification and assessment.

f. Facilities and equipment.

The genetics laboratory at UI is a state-of-the-art DNA analysis unit. Engineering facilities at the UI and WSU hydraulics laboratories are well equipped. The labs have a recirculating pumping capacity of about 2000 gpm. Floor space is available for the physical model. A machine shop and a lab technician are available for model construction and modification. An ultrasonic flow meter is available to measure the discharge through the model. Yaw and pitch probes are available to determine velocity vector fields. All data will be collected and archived by a PC-BASED data acquisition system. The College of Engineering has a license of FIDAP, Computational Fluid Dynamics Software and a well-established finite element-based CFD package. The newest version of FIDAP (Version 7.62) has the capability to capture fine 3-D resolutions of open channel flow.

USFWS will provide all office space, computer access, vehicles, and equipment for investigative work at the by-pass channel facility. The participating engineers and biologists have survey equipment, flow meters, and all of the measuring equipment needed. The only item of equipment anticipated is a computer for the modeling component. Because of the desired resolution, roughly 250,000 elements are needed in each simulation. A high-powered Pentium II PC with at least 512 meg of RAM is required. Such a FIDAP capable PC is not available at the University and must be purchased.

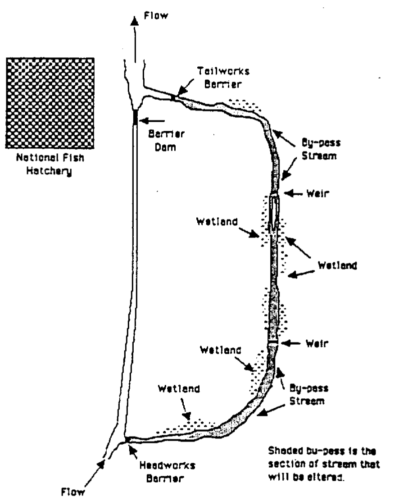

Figure 1. Icicle Creek by-pass channel

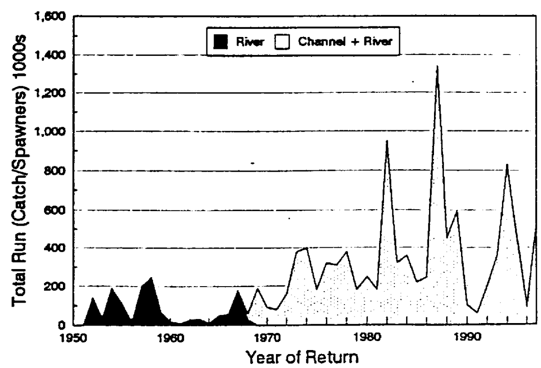

Figure 2. Weaver Creek sockeye production

g. **References**.

Allendorf, F. W. and Utter, F. M. 1979. Population genetics. *In* D. J. Randall, J. S. Hoar, and R. Brett (eds). Fish Physiology, Vol. 8. Academic Press, New York.

Allendorf, F. W. and Phelps, S. R. 1980. Loss of genetic variation in a hatchery stock of cutthroat trout. Trans. Amer. Fish. Soc. 109:537-543.

Bevan, D., J. Harville, P. Bergman, T. Bjornn, J. Crutchfield, P. Klingeman and J. Litchfield. 1994. Snake River Salmon Recovery Team: Final Recommendations to the National Marine Fisheries Service, May 1994.

Brannon, E. L. 1984. Influence of stock origin on salmon migratory behavior. Pages 103-112*in* J.D. McCleave, G.P. Arnold, J.J. Dodson, and W.H. Neill (eds). Mechanisms of Migration . Plenum Press.

Brannon. E.L., 1998. Evolution of Chinook Salmon Racial Structure, University of Idaho press, Moscow ID. 200 pp.

Brett, J.R., W.C. Clarke and J.E. Shelborn. 1982. Experiments of thermal requirements for growth and food conversion efficiency of juvenile chinook *Onchorhynchus tshawytscha.* Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, B.C. Canadian Technical Report of Fisheries and Aquatic Sciences No. 1127.

Chapman, D.W. and T.C. Bjornn. 1969. Distribution of salmonids in streams, with special reference to food and feeding. Pages 153-176 *in* T.G. Northcote, editor. Symposium on Salmon and Trout in Streams. The University of British Columbia, Canada.

Chapman, D., A. Giorgi, M. Hill, S. McCrutcheon, D. Park, W. Platts, K. Pratt, J. Seeb, L. Seeb, F. Utter. 1991. Status of Snake River Chinook Salmon. Prepared for Pacific Northwest Utilities Conference Committee.

Cooper, A.C. 1977. Evaluation of the production of sockeye and pink salmon at spawning and incubation channels in the Fraser River system. International Pacific Salmon Fisheries Commission. New Westminster, B.C. Progress Report No.36. 80 pp.

Cross, T. F. and King, J. 1983. Genetic effects of hatchery rearing in Atlantic salmon. Aquaculture 33:33-40.

Hunt, R.L.. 1993. Trout stream therapy. Univ. Wisc. Press. 74 pp.

Johnson, S.W., J.F. Thedinga and K.V. Koski. 1992. Life history of juvenile ocean-type chinook salmon (*Oncorhynchus tshawytscha*) in the Situk River, Alaska. Canadian of Journal of Fisheries and Aquatic Sciences 49:2621-2629.

Keith, R.M. 1991. Response of juvenile salmonids to riparian and instream cover modifications in small streams flowing through second- growth forests of southeast Alaska. Thesis. College of Graduate Studies, University of Idaho. 62 pp.

Lichatowich, J.A.and L. E. Morbrand. 1995. Analysis of chinook salmon in the Columbia River from an ecosystem perspective. Mobrand Biometrics, Inc. USDE, BPA, Division of Fish and Wildlife. Project Number 92-18. 102 pp.

Moriarty, D. and R. Pullin. 1987. Detritus and microbial ecology in aquaculture. Proceeding of the Conference on Detrital Systems for Aquaculture. ICLARM. August 1985, Bellagio, Como, Italy. 420 pp.

Mullan, J.W., K.R. Williams, G. Rhodus, T.W. Hillman, and J.D. McIntyre. 1992. Production and habitat of salmonids in mid-Columbia River tributary streams. U.S. Fish and Wildlife Service, Monograph I. 486 pp.

Murphy, M.L. and W.R. Meehan. 1991. Stream ecosystems. Pages 17-46 *in* Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication 19.

Northwest Power Planning Council. 1994. 1994 Columbia River Basin Fish and Wildlife Program. Northwest Power Planning Council 94-2 (January), Portland, OR.

Platts, W.S., C. Armour, G.D. Booth, M. Bryant, J.L. Bufford, P. Cuplin, S. Jensen, G.W. Lienkaemper, G.W. Minshall, S.B. Monsen, J.R. Sedell and J.S. Tuhy. 1987. Methods for evaluating riparian habitats with application to management. USDA Forest Service Intermountain Research Station, General Technical Report INT-221. 177 pp.

Platts, W.S and R.L. Nelson. 1989. Stream canopy and its relationship to salmonid biomass in the intermountain west. North American J. Fish. Management. 9:446-457.

Reiser, D.W. and T.C. Bjornn. 1979. Influence of forest and rangeland management on anadromous fish habitat in western North America - Habitat requirements of anadromous salmonids. USDA Forest Service, Anadromous Fish Habitat Program, Pacific Northwest Forest and Range Experiment Station, General Technical Report PNW-96. 54 pp.

Rich, A.B. and C.E. Petrosky. 1994. Idaho habitat & natural production monitoring: Part I. USDE, BPA, Division of Fish and Wildlife. Project Number 91-73. 33pp.

Roper, B.B. and D.L. Scarnecchia. 1994. Summer distribution of and habitat use by chinook salmon and steelhead within a major basin of the South Umpqua River, Oregon. Trans. Amer. Fish. Soc. 123:298-308.

Rubin, S.P., T.C. Bornn and B. Dennis. 1991. Habitat suitability curves for juvenile chinook salmon and steelhead development using a habitat-oriented sampling approac. Rivers 2:1 12-29.

Ryman, N. and Stahl, G. 1980. Genetic changes in hatchery stocks of brown trout (*Salmo trutta*). Can. J. Fish. Aquat. Sci. 37:82-87.

Stahl, G. 1983. Differences in the amount and distribution of genetic variation between natural populations and hatchery stocks of Atlantic salmon. Aquaculture 33:23-32.

Swain, D. P. and Riddell, B. E. 1990. Variation in agonistic behavior between newly emerged juveniles from hatchery and wild populations of coho salmon, *Oncorhynchus kisutch*. Can. J. Fish Aquat. Sci. 47:566-571.

Taylor, E.B. 1990. Environmental correlates of life-history variation in juvenile chinook salmon, *Oncorhynchus tshawytscha* (Walbaum). Journal of Fish Biology 37:1-17.

Weaver, L.A. and G.C. Garman. 1994. Urbanization of a watershed and historical changes in a stream fish assemblage. Trans. Amer. Fish. Soc. 123:162-172.

Welsh, T.L. 1994. Interactive Dominance: Chinook Salmon and Eastern Brook Trout. Ph. D. Dissertation. University of Idaho. Moscow, Idaho.

Section 8. Relationships to other projects

The proposal for construction and evaluation of engineered stream channels as a new concept in natural-type chinook salmon production supplementation, is a project that is associated with every supplementation and production hatchery in the Pacific Northwest. Natural-type supplementation rearing channels could become a management tool to assist in enhancement programs associated with irrigation systems and reservoirs. It could become a technology adopted by hatcheries, eventually replacing standard hatchery techniques. If such engineered stream channels produce smolts that survive only half as well as wild fish, based on hatchery survival of Snake River chinook salmon, the benefit of engineered streams in adult returns would be 10 times greater for the same facilities cost, and closer to 20 times greater considering the reduced cost of such engineered stream channel facilities. Production per mile of channel is expected to be greater than 10,000 smolts, or between 100 and 500 adults returns, providing a spawner base much greater than is required to sustain the population.

The project is in collaboration with WSU and USFWS to provide diversity in expertise and experience associated with fish production technology. If the project is successful in producing high quality fish, the USFWS is planning to apply the technology at other of their hatchery sites for supplementation. Collaboration also concentrates expertise in otherwise diverse fields of interest into a complementary team to address a special bio-engineering problem.

Interest in the project was expressed by the combined Washington State Senate and House Natural Resources Committee. The concept was presented at their November meeting held at Hood Canal and was endorsed in a Senate Bill being prepared for the coming legislative session. Interest in the concept by irrigators and the USFWS is expressed in the letters attached to the proposal. USFWS in-kind contributions over the period of the study is estimated to amount to $200,000. E. Brannon has an NSF (EPSCoR) grant ($30,000) that would fund the genetics monitoring for diversity, habitat evaluation, and a Ph.D. student in habitat engineering.

Section 9. Key personnel

Ernest Leroy Brannon

Aquaculture Research Institute
University of Idaho
Moscow, Idaho 83844-2260

EDUCATION:

PH.D., Fisheries, University of Washington, 1973
B.S., Fisheries, University of Washington, 1959

EXPERIENCE:

1988-present: Director, Aquaculture Institute, University of Idaho, Moscow, Idaho
1984-1988: Professor, School of Fisheries, College of Ocean and Fisheries Sciences, University of Washington, Seattle

RESEARCH EXPERIENCE:

Major areas of research include fish farm effluent and water quality studies, aquaculture technology development, feed trials and fish nutrition, artificial propagation, critical life history phases and migratory behavior of salmonids, habitat research and enhancement, reproduction and genetics.

EXPERTISE:

E. Brannon is a professor in fisheries, and Director of the UI Aquaculture Research Institute. He has an extensive background in chinook salmon life history and salmonid aquaculture, and has personal experience in the construction and evaluation of sockeye and pink salmon spawning channels in British Columbia. Dr. Brannon will lead the chinook salmon biological, genetics, and habitat team assessments required for design specifications and evaluation.

PUBLICATIONS:

Brannon, E.L. Evolution of chinook salmon population structure. In preparation.

Brannon, E.L. Columbia River downstream migrant passage and habitat recovery. Pages __ - __ in E.L. Brannon, editor. Proceedings of the Columbia River anadromous salmonid rehabilitation and passage symposium (June 5-7, 1995, Richland, WA). Sponsored by the University of Idaho and Washington State University. Submitted for publication.

Brannon, E.L, J. Easterbrooks, W. Larrick, D. Robinson, D. Simmons, and B. Tuck. Title XII Yakima River flow recommendations. Yakima River System Operations Advisory Committee report to Congress and the Secretary of the Interior. In preparation.

Cummings, S.A., E.L. Brannon, K. Adams, and G.H. Thorgaard. 1997. Genetic analyses to establish captive breeding priorities for endangered Snake River sockeye salmon. Conservation Biology 11(3):662-669.

Brannon, E. L. and A. W. Maki. 1996. The *Exxon Valdez* Oil Spill: Analysis of Impacts on the Prince William Sound Pink Salmon. Reviews in Fisheries Science. In preparation.

JIM C. P. LIOU, Ph.D., P.E.

Associate Professor of Civil Engineering
Department of Civil Engineering
University of Idaho
Moscow, Idaho 83843

EDUCATION:

B.S., Agricultural Engineering, 1969, National Taiwan University, Taipei, Taiwan
M.S., Civil Engineering, 1972, University of Idaho, Moscow, Idaho
Ph.D., Civil Engineering, 1976, University of Michigan, Ann Arbor, Michigan

EMPLOYMENT:

Stoner Associates, Inc., Senior Staff Engineer and R/D Manager/1979-1986
University of Idaho, Assistant Professor, Associate Professor/1986-present

EXPERTISE:

J. Liou is an associate professor in civil engineering at UI, and is a registered professional engineer in Idaho, Michigan, and Pennsylvania. He has expertise in hydraulic structures, hydraulic modeling, and hydraulic engineering. Dr. Liou will have primary responsibility for the hydraulic model and performance of the stream channel design.

RELEVANT EXPERIENCE:

Hydraulic structures modeling and flow meter calibration at Taipei Hydraulic Laboratory, 1967-1969
Cross-sectional survey and discharge measurements of Tamsui estuary and its tribytaries, Taipei, Taiwan, 1969-1971
Theoretical and physical model studies of wake size behind partially submerged roughness elements in open channels, University of Idaho, 1971-1972
Numerical simulations, physical modeling, and field studies of mixing zones resulted from thermal discharges into natural rivers, 1977-1979
Riprap design for dike confining a cooling lake of a power plant. Riprap repair and safeguard design against jet impangement. 1978
Physical modeling of the flow field near the regulating outlets of the Dworshak Dam for the purpose of exploring alternatives to minimize Kokanee entrapment, 1997

REGISTRATIONS:

Registered Professional Engineer in Idaho, Michigan, and Pennsylvania

SELECTED PUBLICATIONS:

Liou, C.P., and Tian, J., 1995a, "Leak Detection - A Transient Flow Simulation Approach," Journal of Energy Resources Technology, ASME, September 1995, Vol. 117, No. 3, pp. 243-248.

Liou, C. P., and Tian, J., 1995b, Real-Time Monitoring of Natural Gas Pipelines - a feasibility Study, Technical Report GRI-95/0239, Gas Research Institute, Chicago, Illinois.

Liou, C.P., and Hunt, W.A., "Filling of Pipelines with Undulating Elevation Profiles," Journal of Hydraulic Engineering, ASCE, Vol. 122, No. 10, pp. 534-539.

Liou, C. P., “Leak Detection by Mass Balance Effective for Norman Wells Line,” Oil & Gas Journal, Vol. 94, No. 17, 1996, pp. 69-74, PennWell Publishing Company, Tulsa, Oklahoma.

Liou, C. P., “Pipeline Integrity Monitoring Using System Impulse Response,” Proceedings of the 1st

International Pipeline Conference, Vol. 2, pp. 1137-1142. ASME, June 9-14, 1996.

WILLIAM C. KINSEL
Washington State University
100 Sprout Road
Richland, WA 99352

EDUCATION:

University of Nebraska	B.S. Civil Engineering	1958
University of Washington	M.S. Mechanical Engineering	1963
University of Nebraska	Ph.D. Engineering Mechanics	1966

EXPERIENCE:

1981 to Date Associate Professor and Coordinator
Mechanical Engineering Program
Washington State University, Richland, WA

EXPERTISE:

Kinsel is an associate professor in mechanical engineering at WSU, and is a registered professional engineer in Washington. He has expertise in mechanical and civil engineering, and extensive experience in fluid mechanics. He also is a consulting advisory engineer for the Hanford Technical Services Croup. Dr. Kinsel will have primary responsibilities for the pneumatic gravel cleaning system, the feed delivery systems, the water return supplementation system, temperature modeling with STREAM thermodynamic model, and the egg and alevin channel incubation compartments.

PROFESSIONAL AFFILIATIONS:

Member, American Society of Civil Engineers
Member, American Society of Mechanical Engineers

FUNDED GRANT ACTIVITY:

Westinghouse Hanford Company: *Conceptual Design of Adjustable Intake Level Pump*, Principal Investigator, June 1994 ($5,000).

Battelle Pacific Northwest Laboratory*: Ribbon Channel Rotating Drum of DNA Sequencing System (RPRD*), Principle Investigator, March 1995 ($7,100).

PUBLICATIONS:

W.C. Kinsel, M. K:haleel and S. DeSteese, *Flow Induced Fatigue of Monotube Cantilever Highway Sign Structures*, submitted to ASCE Journal of Structural Engineering, December 1994.

SPONSORED POSITION PAPERS:

W.C. Kinsel and D.G. Lindstrom, *Use of FFTF For Nuclear Cogeneration*, Westinghouse Hanford Company, May 1990.

THOMAS **W. BUMSTEAD, P.E.**
River Masters Engineering
Pullman, Washington

EDUCATION:

M.S., Civil Engineering, Washington State University, 1982
B.S., Fish & Wildlife Management, Montana State University, 1977

EXPERIENCE:

Fisheries Engineering, Fish Passage Design, Habitat Restoration, Stream Channel Restoration, Hydraulic Engineering, Hydrologic Analysis, Fisheries Biology, River Engineering, and Construction Supervision

REGISTRATION:

Professional Engineer:
Washington 1987
Oregon, 1989
Idaho, 1991
Montana, 1993
Certified Scuba Diver

EXPERTISE:

T. Bumstead is a senior engineer at River Masters Engineering. He received his MS in civil engineering and a BS in fish and wildlife at Montana State University. Mr. Bumstead is a registered professional engineer in Washington, Oregon, Idaho and Montana. He has extensive experience in fisheries, with expertise in habitat and stream channel restoration and systems modeling. He also has extensive experience at WSU in hydraulic engineering. Mr. Bumstead will have primary responsibility for the survey assessments and construction manager for the construction phase of the project.

PROFESSIONAL SOCIETIES:

American Fisheries Society
American Society of Civil Engineers

PROJECT EXPERIENCE:

Fish Passage Design
- Little River Falls Fishway Design, Oregon
- Toppenish Creek Diversion Dam Fish Passage Facilities, Washington
- Shotgun Creek and Crooked Fork Passage Barrier Modifications, Idaho
- Smith River Falls Passage Improvements, Oregon

River Engineering
- Coeur d'Alene River Channel Stabilization, Idaho
- Prichard Creek Channel Stabilization, Idaho
- Middle Oregon Indian Museum Stream Bank Protection, Oregon
- Dredging Alternatives for the Pelton Reregulating Dam Tailrace, Oregon

Construction Supervision
- Carpenter Creek Stream Channel Restoration, Idaho
- North Fork Porter Creek Habitat Enhancement, Washington
- Toppenish Creek Diversion Dam Fish Passage Facilities, Washington
- Coeur d'Alene River Channel Stabilization, Idaho

- Red River Meadow Restoration, Idaho

GREGORY A. PRATSCHNER
9585 East Leavenworth Road
Leavenworth, WA 98826

EDUCATION:

M.S., Fisheries, University of Washington. Thesis: "The Relative Resistance of Six Phenotypes of Coho Salmon (*Oncorhynchus kisutch*) to Cytophagosis, Furunculosis, and Vibriosis, 1978
B.S., Fisheries, University of Washington, 1975
Associate of Art and Science, Bellevue Community College, 1973

EXPERIENCE:

1988 – present:	U.S. Fish and Wildlife Service, Leavenworth National Fish Hatchery Complex, Washington. Project leader of this 3 station Pacfic salmon and steelhead hatchery complex.
1984 – 1998	U.S. Fish and Wildlife Service, Dworshak National Fish Hatchery Complex, Idaho. Assistant manager of this Pacific salmon and steelhead hatchery.
1982 – 1984	U.S. Fish and Wildlife Service, Orangeburg/Bears Bluff National Fish Hatchery Complex. Assistant manager of the Bears Bluff unit of this warmwater/anadromous (*i.e.* striped bass and sturgeon) hatchery.
1981 – 1982	U.S. Fish and Wildlife Service, Fisheries Academy, West Virginia. Attended a nine month intensive course in fish hatchery management.
1978 – 1981	U.S. Fish and Wildlife Service, Wolf Creek National Fish Hatchery, Kentucky. Assistant manager of this rainbow trout hatchery.
1975 – 1978	University of Washington, Seattle. Graduate student conducting research on Pacific salmon genetics and pathology. Worked part-time at State of Washington and State of Alaska salmon hatcheries.

EXPERTISE:

G. Pratschner is the USFWS Leavenworth complex manager and has extensive experience in hatchery management and production. He received his MS at University of Washington in genetics and has expertise in protein electrophoresis.   Mr. Pratschner will have responsibility as project manager on the USFWS site at Icicle Creek and will develop any environmental assessment and handle all permit inquiries necessary for the project. His extensive knowledge of hatchery systems and chinook salmon will also provide assistance in assessment of the engineered stream channel system, and will follow-up with long-range monitoring and evaluation of project chinook salmon performance.

Section 10. Information/technology transfer

Technology transfer will be accomplished through journal publications, the University of Idaho web-site database on fisheries and aquaculture, and concept and results will be presented at conferences on NATURES, hatchery workshops, and other fisheries associations.

Attachments